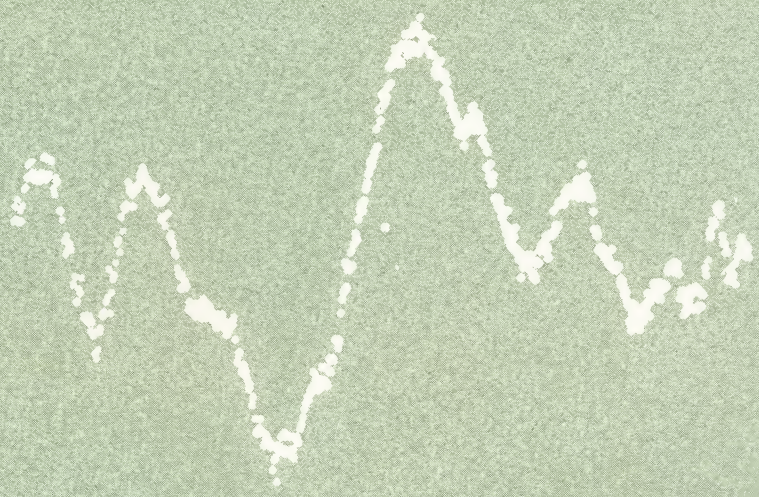
G-4720



# BIOELECTRICAL SIGNAL ANALYSIS WITH PDP-4

DIGITAL EQUIPMENT CORPORATION • MAYNARD, MASSACHUSETTS

In the last decade the digital computer has become an integral and invaluable tool in the physical and chemical sciences. The application of these machines to medicine and biology, however, has been slower in developing, mainly due to the difficulties in quantifying biological data and the tremendous expense involved in utilizing large scale computers.

With the development and marketing of reliable and less expensive machines, which can handle a large variety of inputs, including direct signals such as brain waves, this application has become feasible. The PDP-4 digital computer, designed and manufactured by Digital Equipment Corporation, Maynard, Massachusetts, became available in early 1962 and was found uniquely suited to the requirements of this environment.

The PDP-4 (for Programmed Digital Processor - 4) is a general purpose, high speed, digital computer with a magnetic core memory. The power of this machine lies in its ability to read and internally store instructions and data, reliably manipulate this information at extremely high speeds, and then present the results on an output device in a specified format. It was purposely designed to facilitate the attachment of a large number of diversified devices so that it can collect various types of data from many sources and can distribute and dispatch data to one or more selected destinations out of several possible destinations. It is, therefore, a very flexible instrument. Its high operating speed further facilitates its application to real time problems, wherein the computer must keep pace with the many variables involved in, for example, a biological experiment.

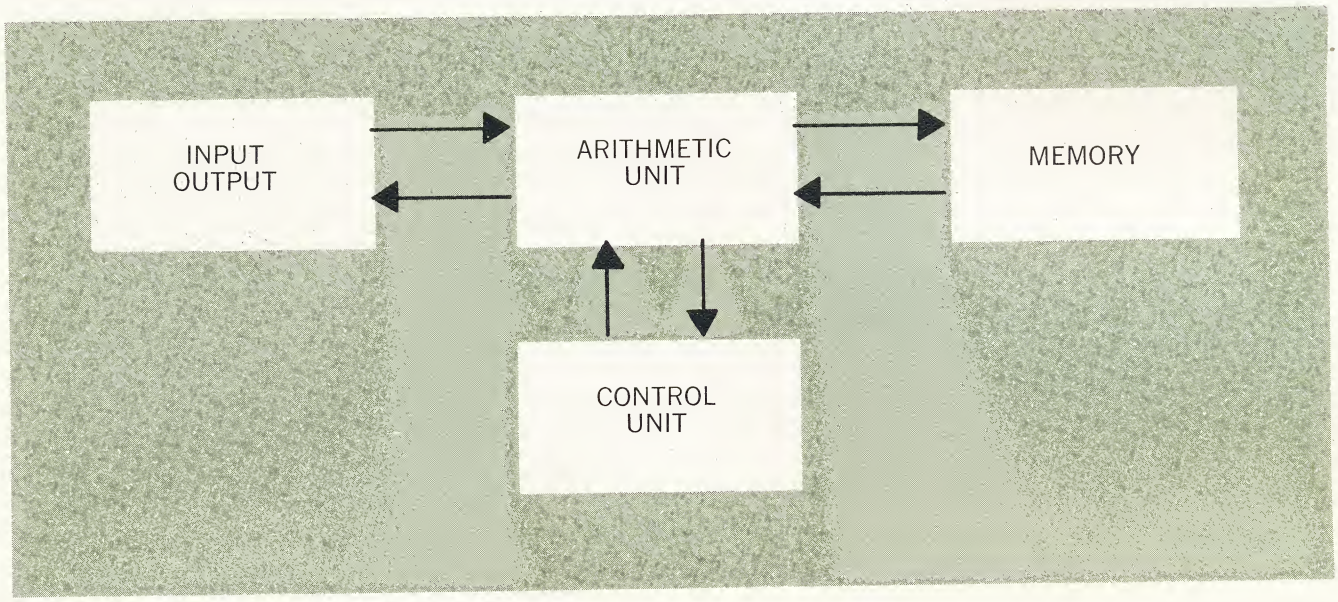
The machine basically consists of four functional sections: (1) a set of input-output components which allows the user to communicate with the machine and vice versa, (2) a memory unit which stores information (instructions and data) for rapid access (3) an arithmetic unit to perform arithmetic operations and (4) a control unit which controls the operation of the system.

In the analysis of electro-physiological responses, the PDP-4 is particularly qualified. It can process responses so quickly that the experimenter can actually see the results of his experiment as he is performing it. As the PDP-4 is a general purpose computer, it will be able to serve the researcher through the course of many and varied experiments. Each new type of Data Processing may be implemented simply by preparing a new computer program, without modifying the existing equipment. Research time can be spent on the actual work of the problem, rather than searching for special equipment for each different application.

A response averaging program has been written for PDP-4 and experiments have been performed using this program. On this particular experiment, an acoustical click was generated and sent to the subject's ear. Electrodes were placed on the subject's scalp to record the response.

After the stimulus occurs, the response is sampled at various time intervals and the results are recorded in the computer memory. As each additional stimulus is presented to the subject, the results are again recorded at the identical intervals and are added to the results already in the memory. These sums are displayed sequentially in time on the computer screen. Thus the sum of the responses may be viewed at all times.

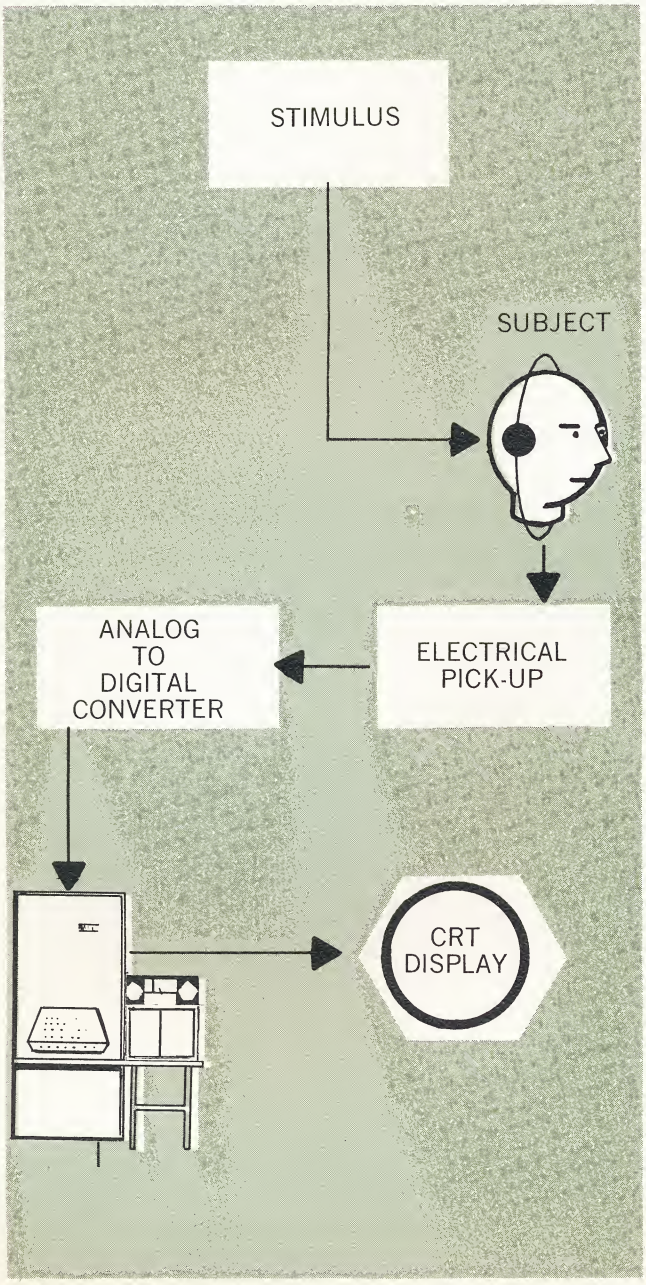
As the number of responses increases, all random variations will tend to average to zero, and the repeated pattern — the evoked response — will reinforce itself. Thus as the number of responses increase the evoked response appears to emerge from the noise.



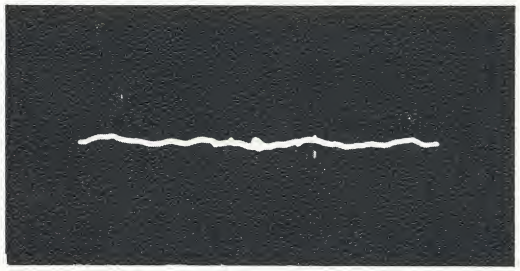

Copyright 1963 by Digital Equipment Corporation

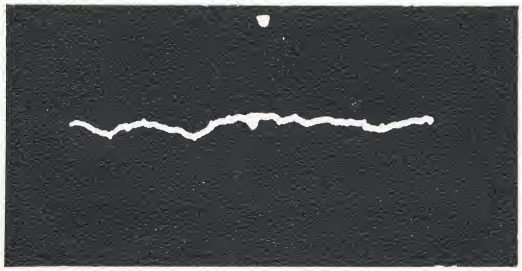
The computer program operates by taking sample points of the response. The amplitude of the response at each point is converted into a digital number as it occurs. The sum of all recordings taken at a particular time after occurrence of the stimuli, is then taken from the computer memory and added to this digital number. The new sum is stored in memory for future use. The sums are displayed, sequentially in time, so that the experimenter can observe how his sum is growing at all times. This on line processing and display allows the experimenter to make any necessary adjustments in the experimental apparatus immediately instead of waiting two or three weeks while the data is processed by hand.

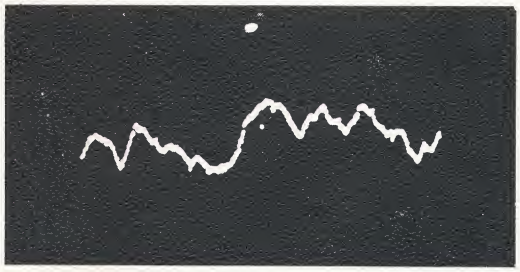
A block diagram explaining the operation of the PDP-4 in this program is shown below.

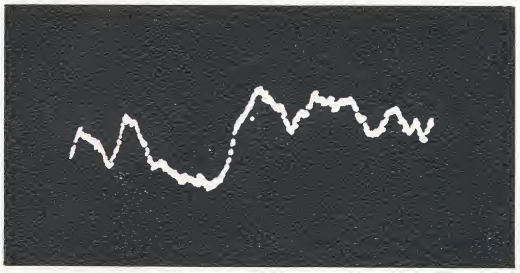


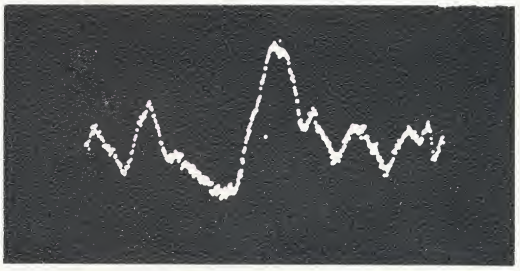

## SUM OF RESPONSES TO ACOUSTICAL CLICKS

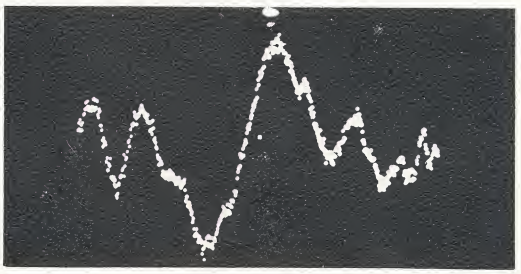

4 Responses


16 Responses


64 Responses


128 Responses


256 Responses


512 Responses

digital

6515 PRINTED IN U.S.A. 25-11/63